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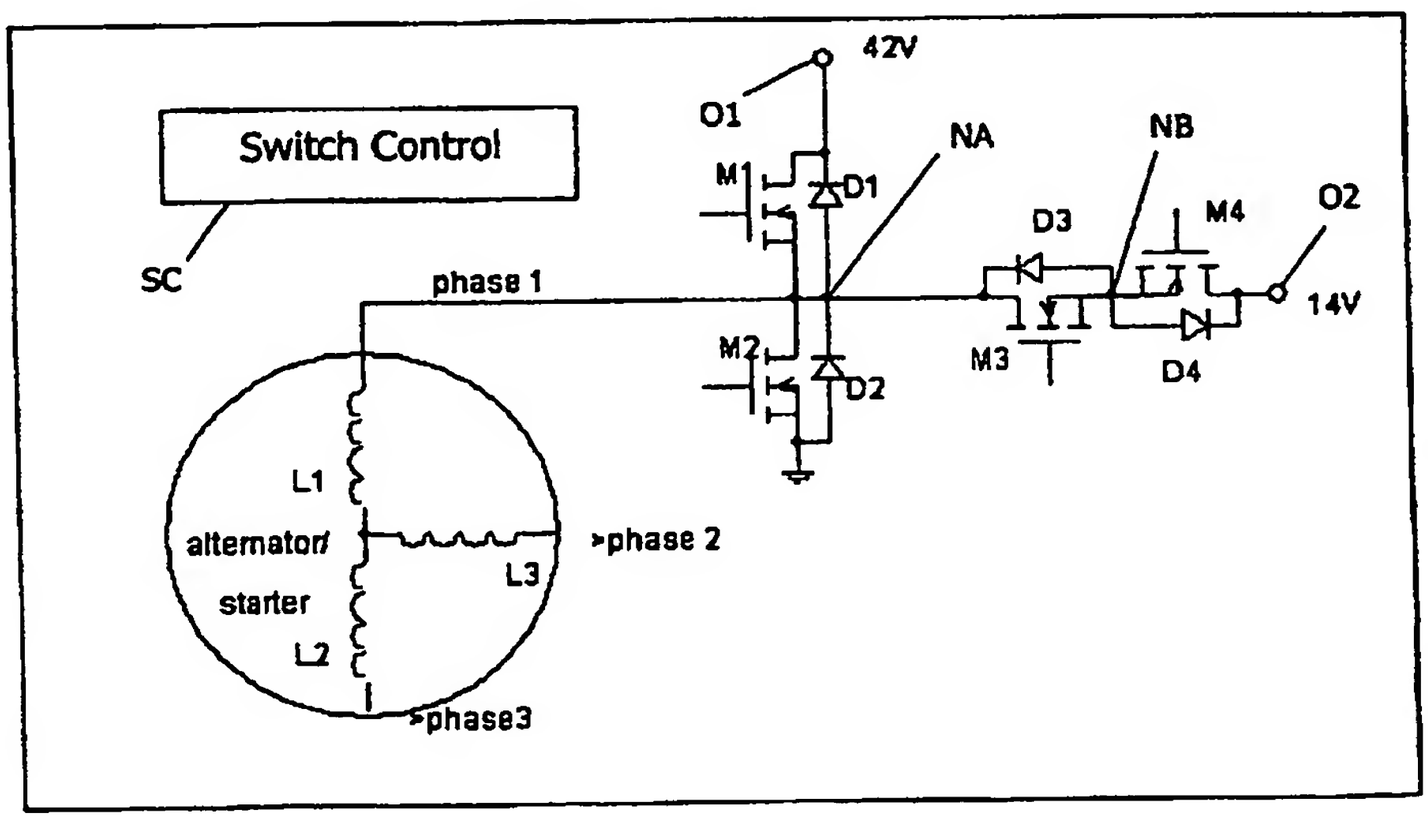
GB 2357641 A

(58) Field of Search
UK CL (Edition S) **H2F FCP FXT FXX , H2H HAK HBCB HBCH HSM**
INT CL[7] **B60R 16/02 , H02J 1/10 7/00 7/14 7/34 , H02M 3/155 3/158**
Online: EPODOC, JAPIO, WPI

(54) Abstract Title
DC-DC converter circuit for use in an automotive integrated starter-alternator (ISA) arrangement

(57) A dual output ISA with integrated bi-directional power converter having: a first node NA for connection to an output from a winding L1, L2, L3 of an alternator-starter (320 Fig 3); first switch means M1 for connection between the first node NA and a first output terminal O1; second switch means M2 for connection between the first node and a datum potential node; third switch means M3 for connection between the first node NA and a second node NB; and fourth switch means M4 for connection between the second node NB and a second output terminal O2. This provides the advantages of low-cost alternator power generation, ability to use jump starting, and avoidance of the need for a separate DC-DC converter.

FIG. 5



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995

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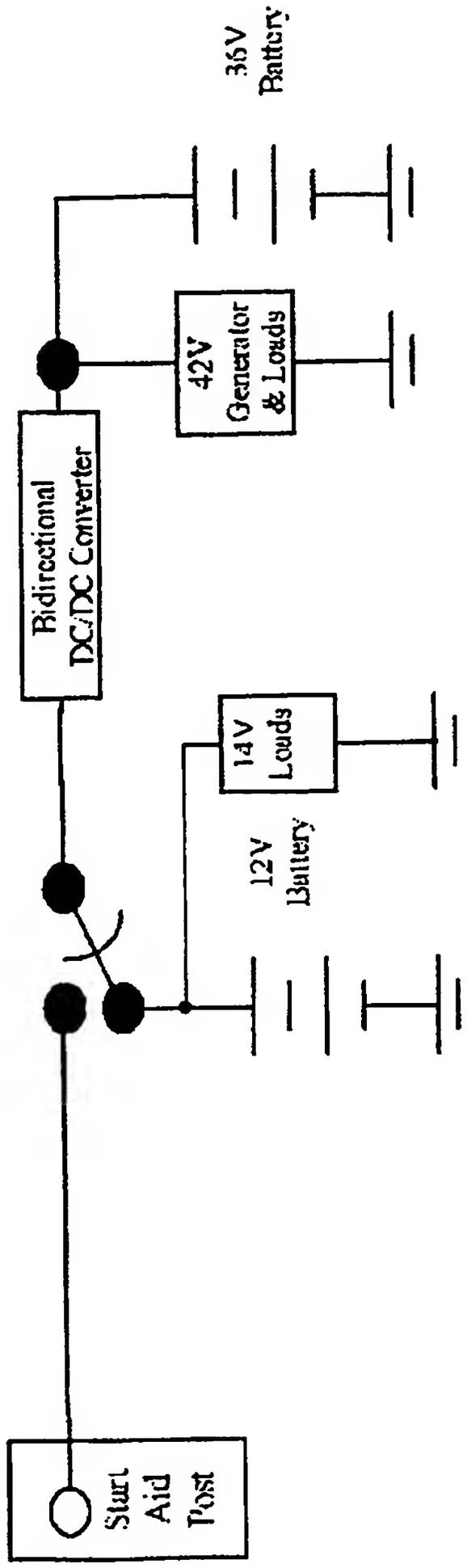


FIG. 1
PRIOR ART

FIG. 2A

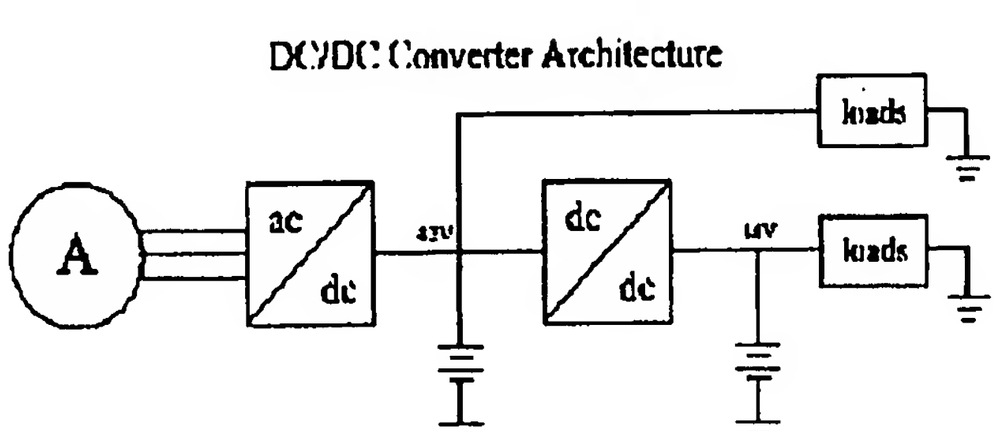
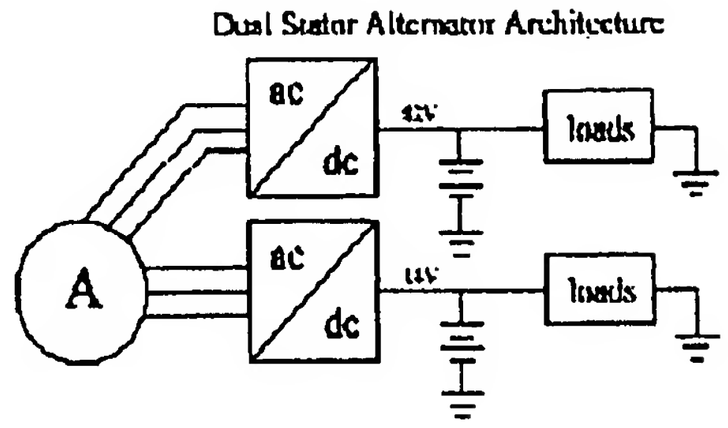


FIG. 2B



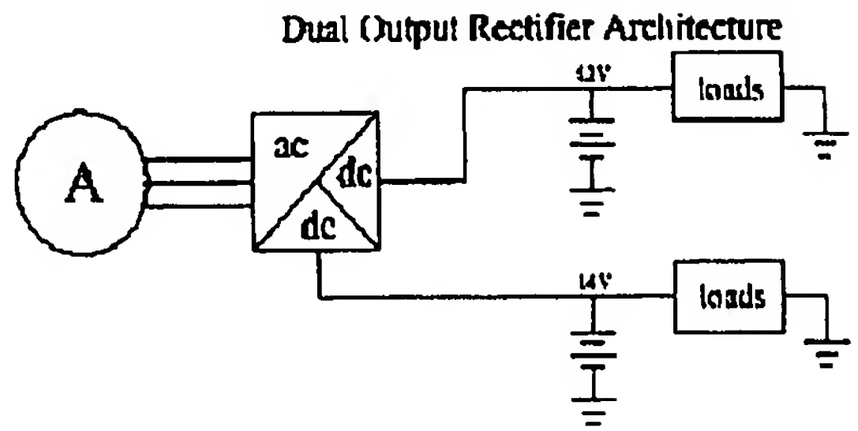


FIG. 2C

FIG. 2
PRIOR ART

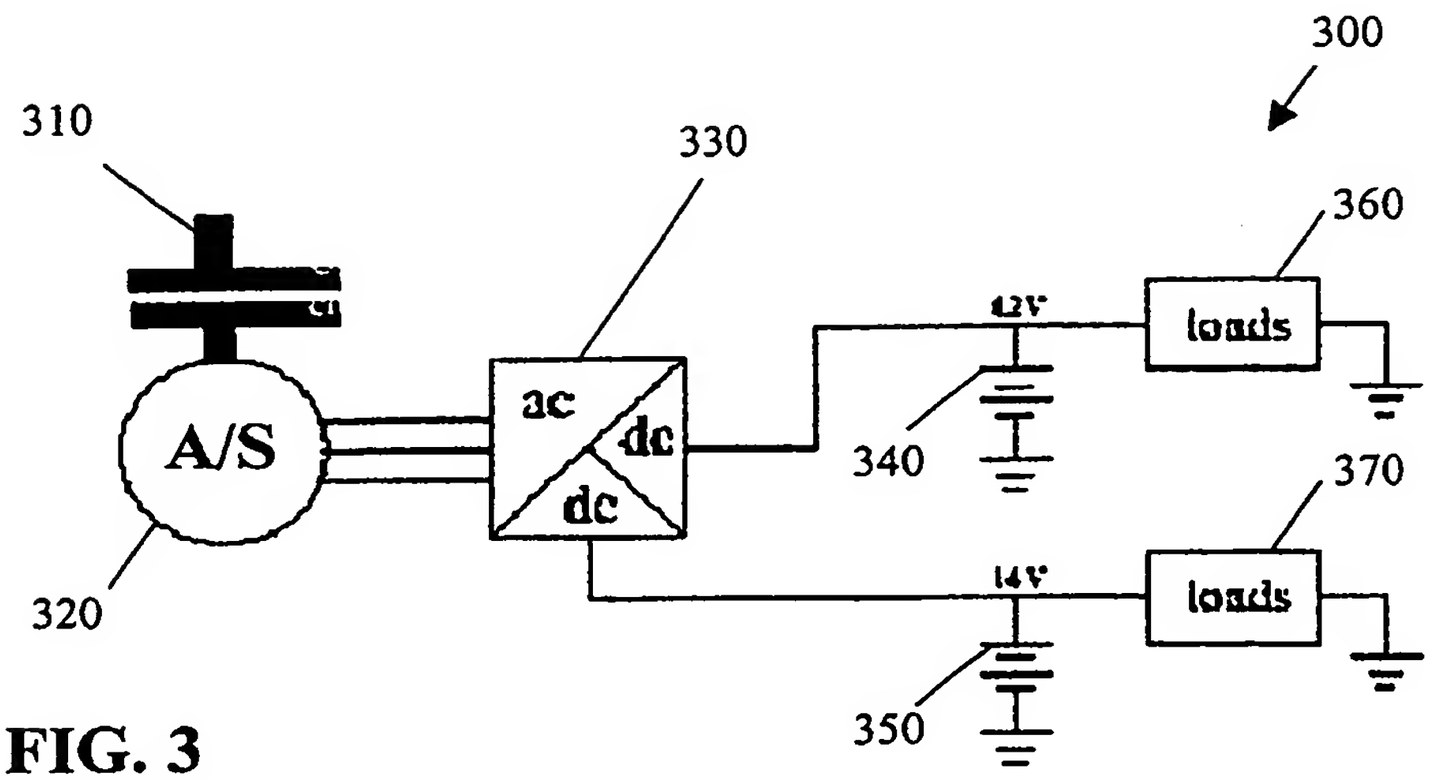

300
310
330
360
42V
loads
A/S
ac
dc
dc
340
370
14V
loads
320
350

FIG. 3

FIG. 4

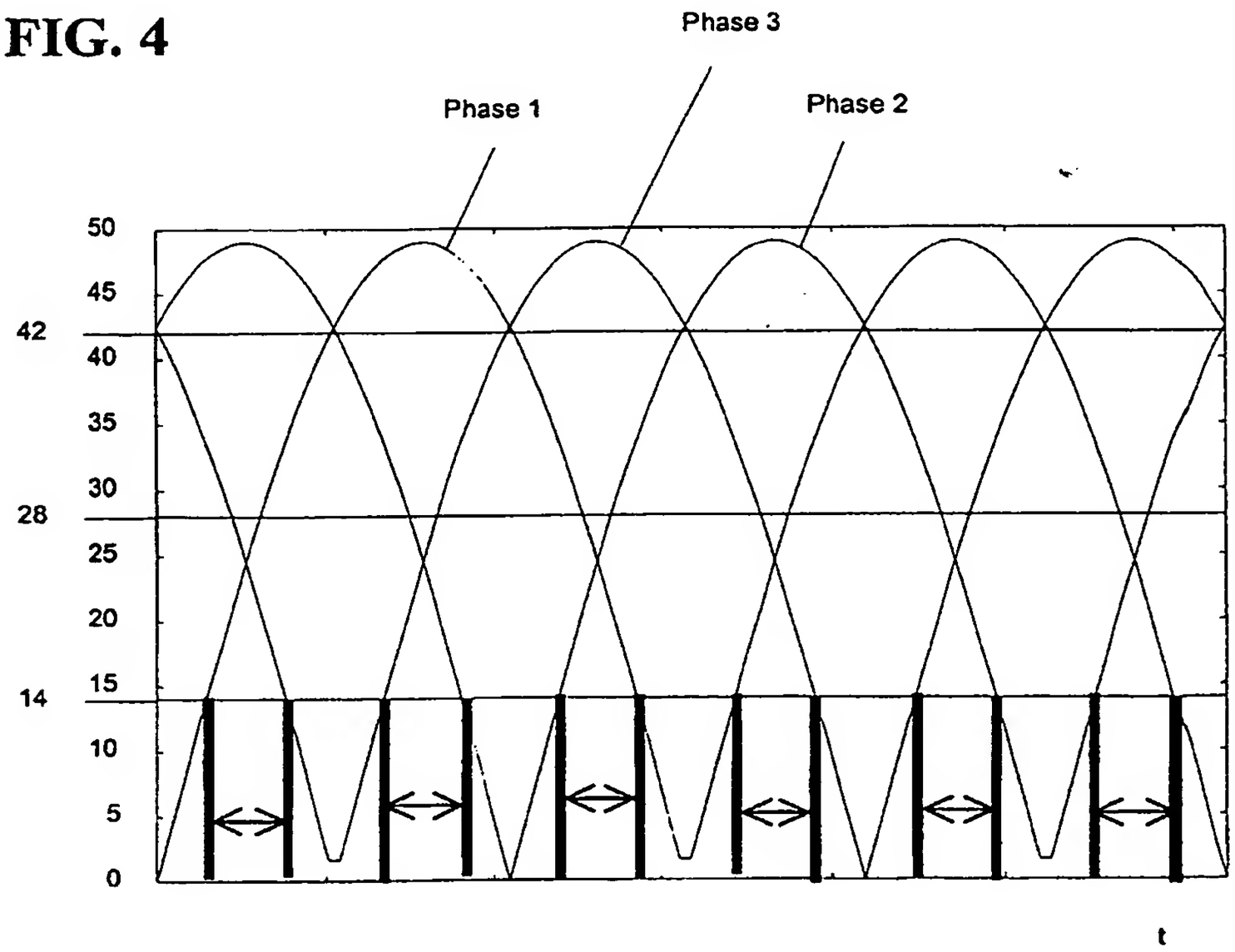

Phase 3
Phase 1
Phase 2
50
45
42
40
35
30
28
25
20
15
14
10
5
0
t

FIG. 5

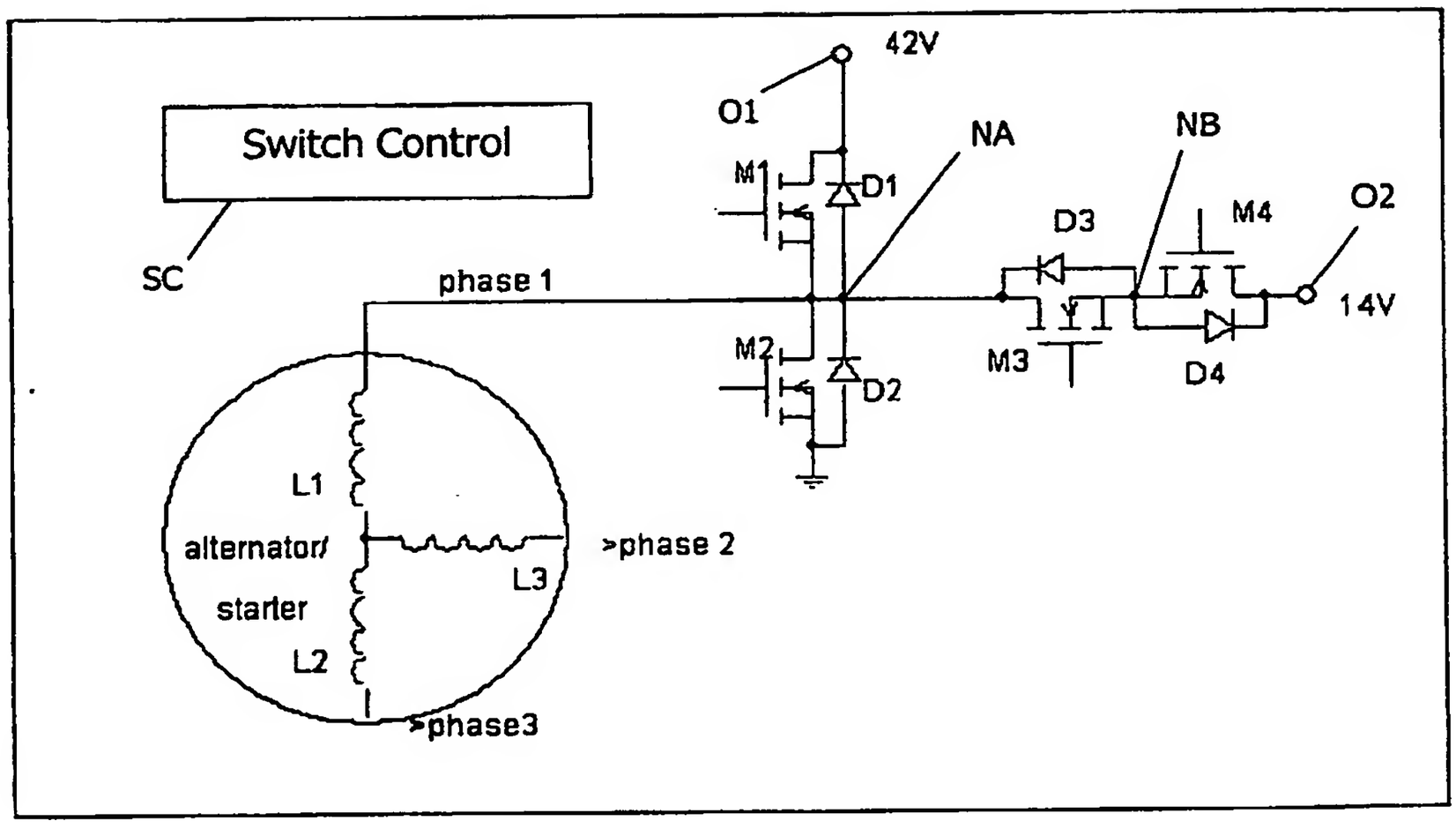

Switch Control
SC
42V
O1
NA
NB
M1
D1
D3
M4
O2
phase 1
14V
M2
M3
D4
D2
L1
alternator/
starter
L2
L3
>phase 2
>phase3

FIG. 6

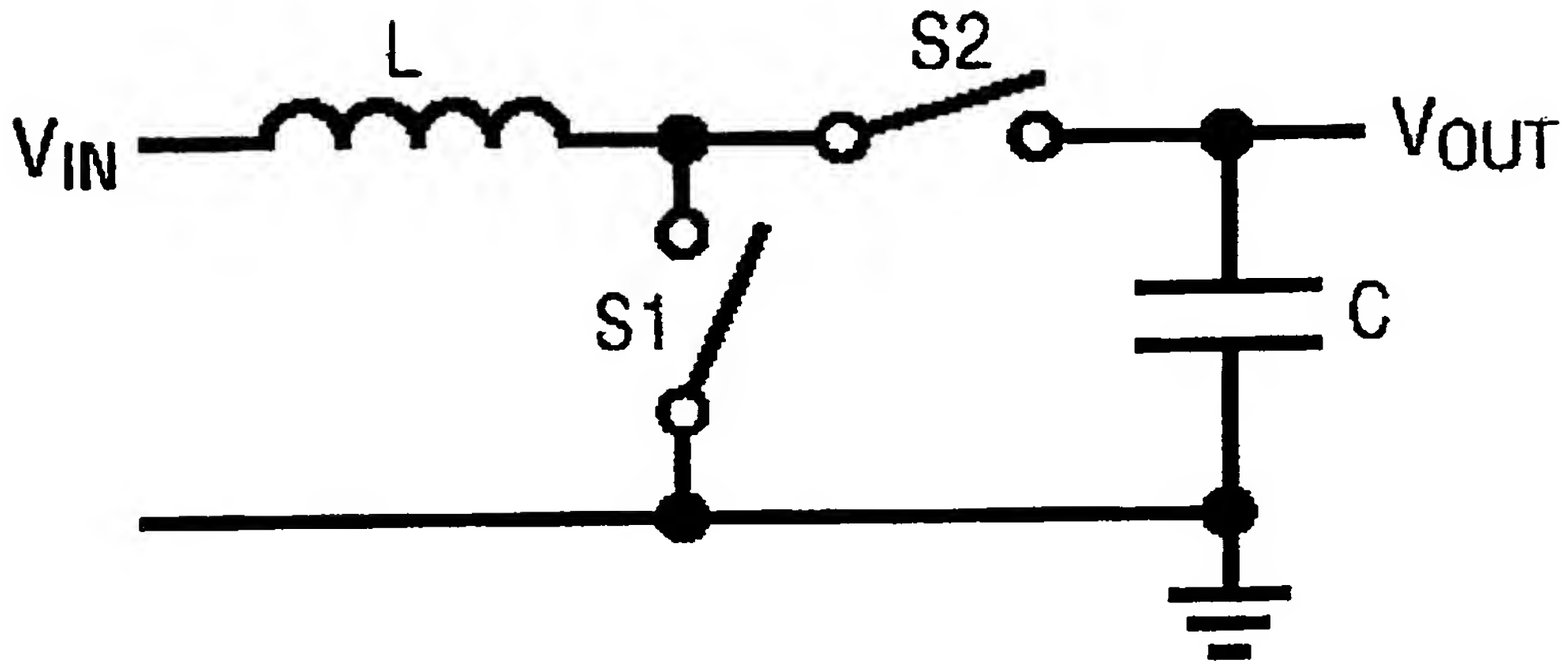
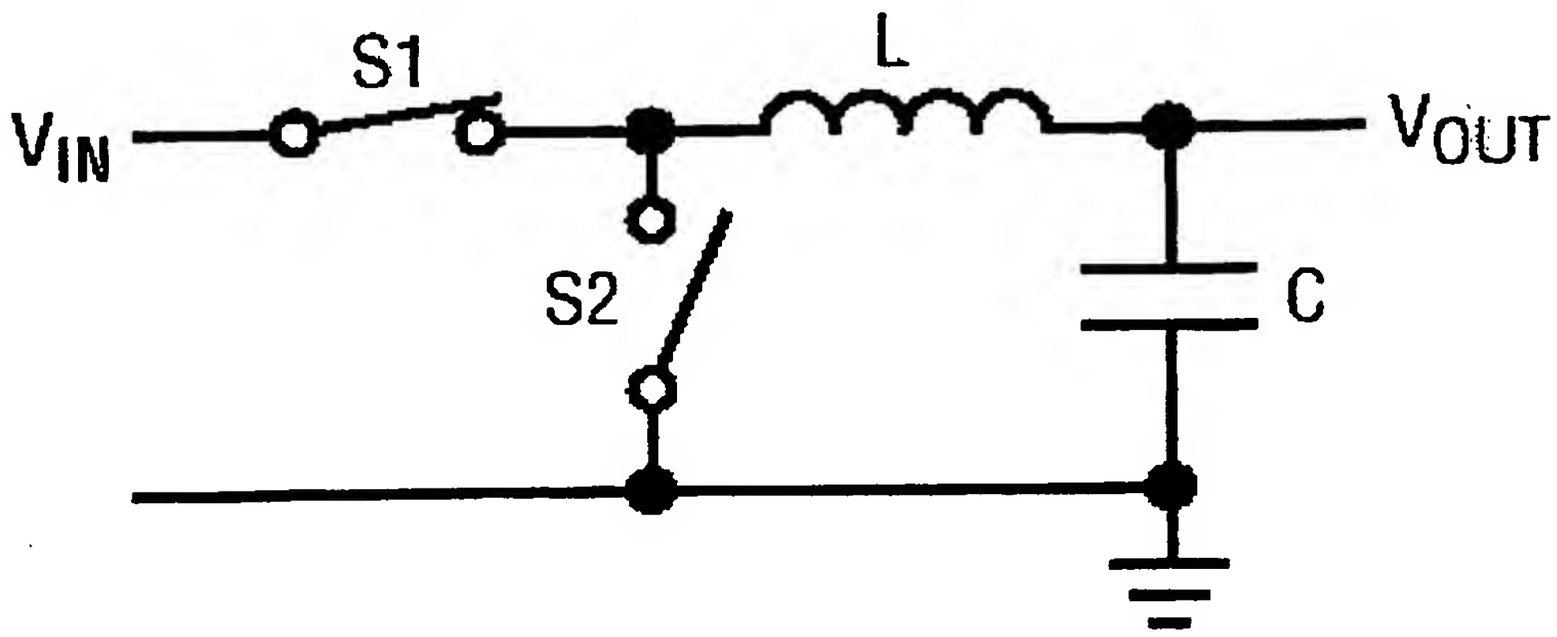


FIG. 7



CIRCUIT FOR USE IN AN AUTOMOTIVE INTEGRATED STARTER-ALTERNATOR (ISA) ARRANGEMENT

Field of the Invention

This invention relates to alternator circuits for use in automotive applications, and particularly to circuits for use in automotive integrated starter-alternator (ISA) arrangements.

Background of the Invention

In the field of this invention current integrated starter-alternator (ISA) arrangements for vehicles having dual voltage 14V/42V systems require the use of a bi-directional DC-DC converter to deal with "jump starts" (starting a disabled vehicle by application of an external DC voltage - typically from another vehicle) from a traditional 12-14V system. However, it is expensive to have to provide a DC-DC converter just for this (rarely used) function. FIG. 1 illustrates a prior art bi-directional DC-DC converter for dealing with "jump starts" from a traditional 12-14V system via a "start aid post".

FIG. 2 illustrates three alternative known approaches for vehicles having dual voltage 14V/42V systems:

FIG. 2A shows a DC-DC converter alternator architecture similar in principle to that illustrated in FIG. 1;

FIG. 2B shows a dual stator alternator architecture; and

FIG. 2C shows a dual output rectifier architecture.

The performance and advantages/disadvantages of these three types of architecture is discussed in detail in the LEES Technical Report TR-00-011 dated 18 October 2000 by Vahe Caliskan entitled "A Dual/High-Voltage Automotive Electrical Power System with Superior Transient Performance" from the Massachusetts Institute of Technology (MIT)/Industry Consortium on Advanced Automotive Electrical/Electronic Components and Systems, particularly at pages 132-141 thereof.

However, although the known architectures of FIG. 2B and particularly that of FIG. 2C offer advantages of efficiency, they do not allow for jump-starting.

It is an object of the present invention to provide dual output ISA with integrated bi-directional power converter wherein the abovementioned disadvantage(s) may be alleviated.

Statement of Invention

In accordance with the present invention there is provided circuit for use in an automotive integrated starter-alternator (ISA) arrangement as claimed in claim 1.

Brief Description of the Drawings

One dual output ISA with integrated bi-directional power converter incorporating the present invention will now be described, by way of example only, with reference to the accompanying drawing(s), in which:

FIG. 1 illustrates a prior art vehicular bi-directional DC-DC converter for dealing with "jump starts" from a traditional 12-14V system via a "start aid post".

FIG. 2A shows a prior art vehicular DC-DC converter alternator architecture similar in principle to that illustrated in FIG. 1;

FIG. 2B shows a prior art vehicular dual stator alternator architecture; and

FIG. 2C shows a prior art vehicular dual output rectifier architecture;

FIG. 3 shows a vehicular integrated starter-alternator (ISA) arrangement, based on the dual output rectifier architecture of FIG. 2C, and incorporating the present invention within its 'AC-DC+DC' converter to allow "jump starting";

FIG. 4 shows a graphical illustration of the three phase outputs of the ISA arrangement of FIG. 3.

FIG. 5 shows a circuit diagrammatic illustration of part of the ISA of FIG. 3.

FIG. 6 shows a simplified circuit diagram illustrating the switching behaviour of the ISA of FIG. 3 operating in "boost" mode; and

FIG. 7 shows a simplified circuit diagram illustrating the switching behaviour of the ISA of FIG. 3 operating in "buck" mode.

Description of Preferred Embodiment(s)

The known dual output rectifier architecture of FIG. 2C is known to provide a low-cost solution for power generation, and its use as a dual output rectifier ISA 300 is shown in FIG. 3. In the dual output rectifier ISA 300, an optional clutch 310 mechanically couples the alternator/starter 320 to the vehicle engine (not shown). The 'AC-DC+DC' converter 330 (which will be explained in greater detail below) provides a 42V output and a 14V output which are connected respectively to a 36V battery 340 and a 12V battery 350 of the vehicle and appropriate loads 360 and 370.

The three phase outputs (Phase 1, Phase2 and Phase 3) of the rectifier arrangement of FIG. 3 are shown FIG. 4. It can be seen that the 42V output is effectively continuous (with ~ 6V of ripple as shown) while the 14V output (shown by the lower portions indicated '<->') is not continuous and may have a larger ripple.

FIG. 5 shows in greater detail part of the 'AC-DC+DC' converter 330. FIG. 5 shows the circuitry associated with just one phase; it is to be understood that identical circuitry is associated with each of the other phases.

The output from the relevant winding L1, L2 or L3 (only that from L1 being shown in detail) of the alternator/starter 310 is connected to a node N. An MOS field effect transistor (MOSFET) switch M1 is connected by its drain and source electrodes between the node NA and a 42V output terminal (O1). A diode D1 is connected across (i.e., in parallel with) the drain and source electrodes of the MOSFET M1. The diode D1 is constituted by the 'body diode' of the MOSFET M1, and so is inherently provided by the MOSFET structure. A further MOSFET switch M2 is connected by its drain and source electrodes between the node NA and a ground terminal. A body diode D2 is connected across the drain and source electrodes of the MOSFET M2.

A MOSFET switch M3 is connected by its drain and source electrodes between the node NA and a node NB. A body diode D3 is connected across the drain and source electrodes of the MOSFET M3. A further MOSFET switch M4 is connected by its drain and source electrodes between the node NB and a 14V output terminal (O2). A body diode D4 is connected across the drain and source electrodes of the MOSFET M4.

Operation of the switch MOSFETs M1, M2, M3 and M4 is controlled by switch control circuitry SC, which may

typically be controlled by microprocessor or microcontroller or dedicated circuitry.

It will be understood that the switching circuitry, described above, of the 'AC-DC+DC' converter 330 allows the 'AC-DC+DC' converter to provide the following:

- Step up DC-DC converter using alternator windings as inductances (used for jump start, receiving aid or to charge internal 36V battery from internal 12V battery) - by operating in "boost" mode as will be described below in relation to FIG. 6.
- Step down DC-DC converter using alternator windings as inductances (used for internal jump starts when internal 12V battery is discharged, but 36V battery is adequately charged) - by operating in "buck" mode as will be described below in relation to FIG. 7. It may be noted that the circuitry inherently provides a structure similar to that described in co-pending GB patent application no. 9929895.2, and may similarly provide a universal up/down bi-directional converter if required.
- 42V ISA - using MOSFETs M1 and M2 (and similar MOSFETs of the other phases) to provide power to the alternator/starter 320 operating as a starter.
- 14V ISA - using MOSFETs M4 and M2 (and similar MOSFETs of the other phases) to provide power to the alternator/starter 320 operating as a starter.
- With the optional clutch 310, the system can be used as a "rotary transformer" from 14<->42V (i.e., it is used as a motor driven from one power rail, and a rectifier to provide power to the other rail).

- 42V ISA generating 14V (as in the above "rotary transformer" operation, but without the clutch and only used during starting).
- 14V ISA generating 42V (as in the above "rotary transformer" operation, but without the clutch and only used during starting).

Referring now to FIG. 6, as referred to above, by application of appropriate voltages to the control electrodes of the MOSFETs M1, M2, M3 and M4, the 'AC-DC+DC' converter 320 can be operated in "boost" mode as follows. As shown in FIG. 6, inductance L is constituted by the series combination of inductance windings L1 and L2 of FIG. 5. Switch S2 is constituted by the diode D1 of FIG. 5, switch S1 is constituted by the MOSFET M2 and the input to the boost mode circuit of FIG. 6 is obtained via the MOSFETs M3 and M4 of phase 3. The capacitance C is provided additionally to the circuitry shown in FIG. 5. It will be understood that operating in boost mode as shown in FIG. 6, with an input voltage (Vin) of 14V, an output voltage (Vout) of 42V is produced.

Referring now to FIG. 7, as referred to above, by application of appropriate voltages to the control electrodes of the MOSFETs M1, M2, M3 and M4, the 'AC-DC+DC' converter 320 can be operated in "buck" mode as follows. As shown in FIG. 7, inductance L is constituted by the series combination of inductance windings L1 and L2 of FIG. 5. Switches S1 and S2 are for example constituted by MOSFETs M1 and M2 of FIG. 5, with MOSFETs M3 and M4 of phase 3 switched on to obtain the 14V output. As in boost mode operation described above, the

capacitance C is provided additionally to the circuitry shown in FIG. 5. It will be understood that operating in buck mode as shown in FIG. 7, with an input voltage (Vin) of 42V, an output voltage (Vout) of 14V is produced.

It will be understood that a "jump start post" may be connected in one of several ways.

1. as a "changeover switch" between the 14V terminal above and the 12V battery/post.
2. as a duplicate set of MOSFETs M3/M4 on each phase (i.e., an extra 6 MOSFETs) - this gives complete flexibility of using any of the above modes from the "jump start post".
3. as a single duplicate set of MOSFETs M3/M4 (i.e., 2 extra MOSFETs) connected between the junction of D1/D2 and the post - this allows both "dc-dc converter" modes of operation and would also allow "conventional" generation of 14V (but with more ripple) as an additional way to give aid.
4. As an extra 3 MOSFETs (one per phase), similar to MOSFET M4, connected between the junction of diodes D3 & D4 and the jump start post. This would power the post at up to ~0.6V (the voltage drop of the diode D4) above the internal 14V line (to allow for voltage drop along the jump start cable), while switching these MOSFETs on would allow receiving aid from the post.

It will be understood the "normal" solution for a 42/14V vehicle would be to use the above system as a 42V ISA (possibly generating 14V during starting if the 12V

battery was flat and 12V was needed for starting) and using the "bi-directional DC-DC converter" arrangement as required for jump starting at 12V (i.e., using jump post scheme 3 above) - in this situation the clutch is not required.

It will be appreciated that for a single rail (42V only vehicle), basically the above approach would be used, but but that in this case components D3/D4/M3/M4 on each phase are clearly not required.

It will be noted also that if ISA operation is not required (i.e., an external starter is available) then MOSFETs M1 and M2 are only required on phase 1 (adding M2 MOSFETs on the other phases will improve the alternator output power, and adding M1 MOSFETs allows full synchronous rectification).

It will further be appreciated that as a further option the same approach may be used with the dual stator alternator approach (e.g., as shown in FIG. 2 above). Careful thought will show all the above configurations are still possible, but in this case a half-bridge is present on each of the (6) phase outputs, and the DC-DC converter solutions use transformer coupling rather than direct inductor coupling. This is however clearly a less attractive option for a 42V only solution.

In conclusion, it will be appreciated that the circuit described above provides the advantages of:

- low-cost alternator power generation,
- ability to use jump starting, and

- avoidance of the need for a separate DC-DC converter.

Claims

1. A circuit for use in an automotive integrated starter-alternator (ISA) arrangement, comprising:

a first node for connection to an output from a winding of an alternator-starter;

first switch means for connection between the first node and a first output terminal;

second switch means for connection between the first node and a datum potential node;

third switch means for connection between the first node and a second node; and fourth switch means for connection between the second node and a second output terminal.

2. The circuit of claim 1 further comprising:

first diode means connected in parallel with the first switch means;

second diode means connected in parallel with the second switch means;

third diode means connected in parallel with the third switch means; and

fourth diode means connected in parallel with the fourth switch means.

3. The circuit of claim 1 or 2 further comprising means for operating the first, second, third and fourth switch means to produce boost mode operation.

4. The circuit of claim 1, 2 or 3 further comprising means for operating the first, second, third and fourth switch means to produce buck mode operation.

5. The circuit of any preceding claim further comprising means for operating the first, second, third and fourth switch means to produce bi-directional DC-DC converter operation.

6. The circuit of any preceding claim further comprising means for connection to a jump start post.

7. The circuit of claim 6 wherein the means for connection to a jump start post comprises switch means connected to the second output terminal.

8. The circuit of claim 6 wherein the starter-alternator has a plurality of phases and the circuit comprises similar circuitry for each of the respective phases, and wherein the means for connection to a jump start post comprises a plurality of switch means of equal number to the plurality of phases and connected respectively to the second terminals of the circuitry of each of the phases.

9. The circuit of claim 6 wherein the means for connection to a jump start post comprises switch means connected to the first node.

10. The circuit of claim 6 wherein the starter-alternator has a plurality of phases and the circuit comprises similar circuitry for each of the respective phases, and wherein the means for connection to a jump start post comprises a plurality of switch means of equal number to the plurality of phases and connected respectively to the second nodes of the circuitry of each of the phases.

11. The circuit of any preceding claim wherein the circuit is arranged to produce in use a potential of substantially 42V at the first output terminal.

12. The circuit of any preceding claim wherein the circuit is arranged to produce in use a potential of substantially 14V at the second output terminal.

13. The circuit of any one of claims 1 to 6 or 11 or 12 wherein the starter-alternator has a plurality of phases and the circuit comprises similar circuitry for each of the respective phases.

14. A circuit for use in an automotive integrated starter-alternator (ISA) arrangement substantially as hereinbefore described with reference to FIGs. 3-7 of the accompanying drawings.

INVESTOR IN PEOPLE

14.

Application No: GB 0107350.1
Claims searched: All

Examiner: Brian Ede
Date of search: 4 September 2001

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): H2F(FCP, FXT, FXX) H2H(HAK, HBCB, HBCH, HSM)

Int Cl (Ed.7): B60R 16/02 H02J 1/10 7/00 7/14 7/34 H02M 3/155 3/158

Other: Online: EPODOC, JAPIO, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X E	GB 2357641 A (MOTOROLA) see especially Fig 3	1-6

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.